

# Magnetic relaxation and magnetization field dependence measurements in $\text{La}_{0.5}\text{Ca}_{0.5}\text{MnO}_3$

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## Abstract

We reported a systematic change in the average magnetic relaxation rate, after the application and removal of a 5 T magnetic field, in a polycrystalline sample of  $\text{La}_{0.5}\text{Ca}_{0.5}\text{MnO}_3$ . Magnetic relaxation measurements and magnetization versus field curves were taken from 10 K to 160 K. The long time behavior of the relaxation curves was approximately logarithmic in all cases.

Keywords: Charge Ordering, Relaxation, Magnetic measurements

Charge ordering compounds have a large variation of resistivity and magnetization as a function of temperature and magnetic field<sup>1,2</sup>. A representative example,  $\text{La}_{0.5}\text{Ca}_{0.5}\text{MnO}_3$  has a paramagnetic-ferromagnetic transition around 265 K and a ferromagnetic-antiferromagnetic (FM-AFM) phase transition at 160 K<sup>3</sup>. Accompanying the FM-AFM transition there is also a charge disordered to a charge ordered phase transition<sup>3</sup>.

Polycrystalline samples of  $\text{La}_{0.5}\text{Ca}_{0.5}\text{MnO}_3$  were prepared by the solid-state method described elsewhere<sup>4</sup>. X-ray diffraction measurements pointed out high quality samples. Magnetization measurements were done with a standard MPMS-5S SQUID magnetometer. The relaxation measuring procedure was the following: first, the sample was heated to 400 K in zero magnetic field; second, the remanent magnetic field in the solenoid of the SQUID magnetometer was set to zero; third, the sample was cooled down to the working temperature

in zero magnetic field; fourth, an applied magnetic field ( $H$ ) was increased from 0 to 5 T at a rate of 0.83 T/minute and remained applied for a waiting time  $t_w=50$  s; fifth,  $H$  was decreased to zero at the same rate; finally, when  $H$  was zero (we defined this time as  $t=0$ ) the  $M(t)$  curve was recorded for more than 210 minutes.

Figure 1 shows magnetic relaxation measurements from 10 K to 160 K. To facilitate the comparison between curves at different temperatures, the magnetization in each case has been normalized to the corresponding value at  $t=0$ . As can be seen, the average relaxation rate (mean slope of each curve) decreases systematically with increasing temperatures from 10 K to 150 K. It is important to note that slopes here are negatives. The absolute ratio of magnetization change, between the initial and the last measurement made, at 10 K is only 1 %, while at 150 K is about 20 %. This qualitative behavior is expected because an increase in the thermal energy should produce a faster relaxation in the magnetization. However, as was reported before<sup>5</sup>, the average relaxation rate increases between 150 K and 195 K. The curve corresponding to 160 K, that illustrates this point, is included in figure 1.

Figure 2 shows representative measurements of the magnetization field dependence. These curves have been explained considering two phases: ferromagnetic droplets immersed in the charge ordered antiferromagnetic matrix<sup>6</sup>. All curves present a rapid increase in the magnetization at low field values, due to the orientation of the ferromagnetic droplets. At about 0.4 T the magnetization starts to increase at a slower rate, showing the gradual annihilation of the antiferromagnetic phase. A small hysteresis is found in the curves from 10 to 140 K. However, for 150 K and 160 K, the magnetization increases rapidly for field above 3 T and the hysteresis grows, reflecting the complete destruction of the antiferromagnetic phase.

The relaxation measurements at long time scales follow approximately a logarithmic law. This logarithm-like relaxation has been found in spin glass systems<sup>7</sup> and mixture of small ferromagnetic particles<sup>8</sup>. The logarithmic relaxation has been attributed to the distribution of energy barriers separating local minima, which correspond to different equilibrium states<sup>7,8</sup>. As seen in figure 2, our sample of  $\text{La}_{0.5}\text{Ca}_{0.5}\text{MnO}_3$  has a mixture of ferromag-

netic and antiferromagnetic domains, which produce frustration in the interactions among individual spins. A systematic fitting of all relaxation curves will be published elsewhere.

Concluding, we presented a systematic decrease in the average magnetic relaxation rate from 10 K to 150 K in a polycrystalline sample of  $\text{La}_{0.5}\text{Ca}_{0.5}\text{MnO}_3$ . The long time behavior of the relaxation curves was approximately logarithmic in all cases. We thank FAPESP, CAPES, CNPq and PRONEX for financial support.

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Figure 1. Normalized magnetic relaxation measurements after applying and removing an applied magnetic field of 5 T. Time is shown in logarithmic scale. The large arrow indicates the direction of increasing temperatures and decreasing relaxation rates (slope more negative) between 10 K and 150 K. Also shown is the curve for 160 K that presents a higher relaxation rate in comparison with the one at 150 K.

Figure 2. Magnetization versus applied field curves for temperatures around 150 K and one representative curve of the low temperature behavior. Magnetization is given in Bohr magnetons per manganese ion.

Figure 1, J. López et. al.

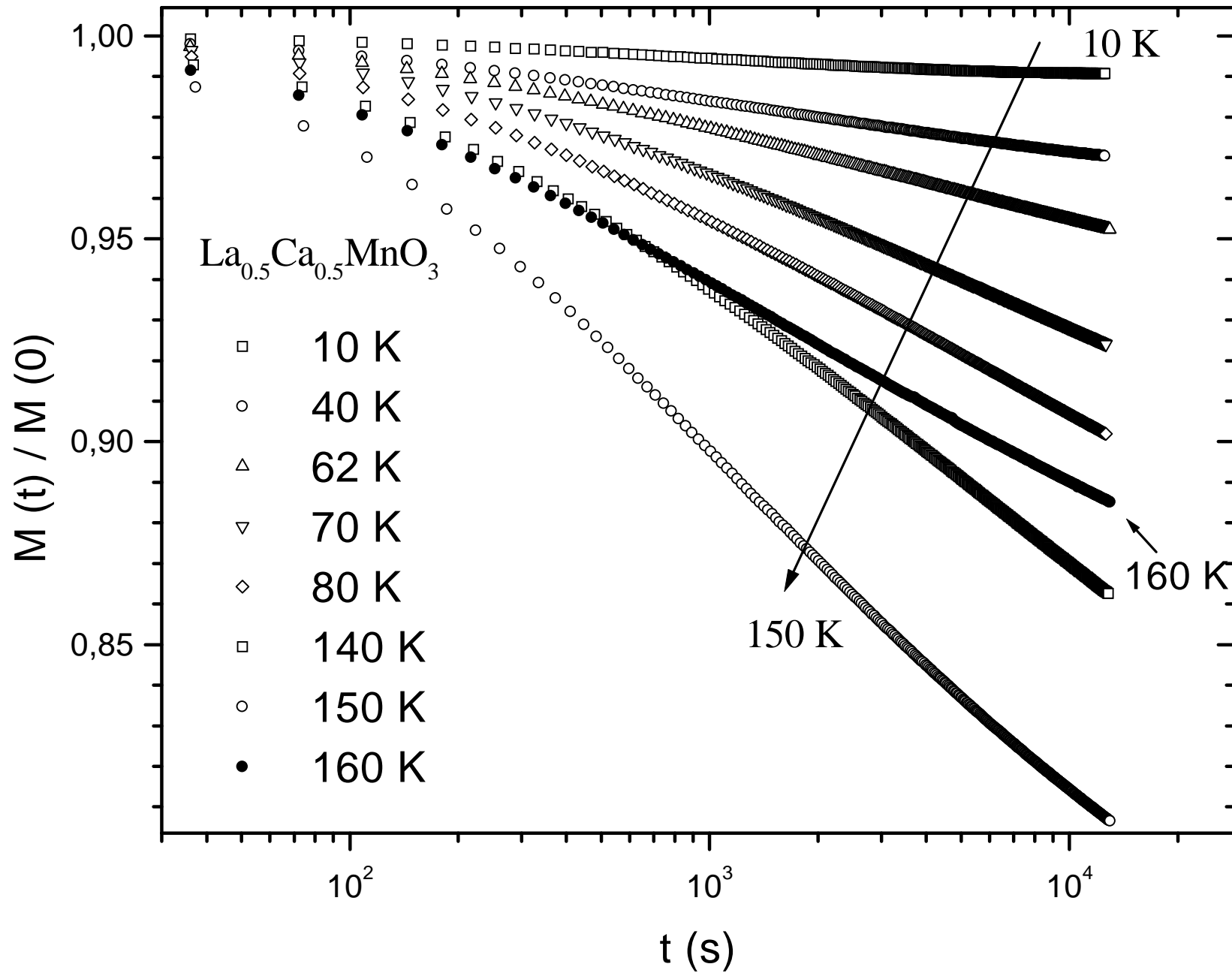


Figure 2, J. López et. al.

